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REFEREED PAPER

The Emergence of an Environmental Cartography in Denmark

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Within the history of cartography, relatively little attention has been devoted to the study of the growing body of maps and spatial data focusing on environmental issues. This is rather surprising, considering the importance of this type of cartography in the handling of the complex environmental problems of modern society. This paper analyses the development of thematic maps and spatial data focusing on the terrestrial environment of Danish landscapes. The paper is introduced with a review of the concept of environmental cartography, followed by a historical analysis of the development of environmental mapping in Denmark. Results suggest that there has been a change in the content and aim of environmental cartography in the twentieth century, from an initial focus on mapping potentials for land use improvement and optimization of the economic outputs from engagement with terrestrial ecosystems, to a focus on monitoring ecosystems and regulation of human intervention. Finally, the usefulness of the concept environmental cartography to frame analytical work dealing with the still increasing number of maps produced for environmental purposes within the history of cartography, is evaluated.

Keywords: environment; landscape maps; environmental regulation; land use; land cover; digital cartography; ecosystems

INTRODUCTION

Maps with the human environment as their central subject matter have been used for centuries. They are typically produced to assess the potential for exploitation of natural resources, for monitoring and mitigation of environmental change and for regulation of environmental risk and calamities related to anthropogenic transformations of natural- and semi-natural ecosystems (Kelmelis, 2003). In a Danish context, key examples include the mapping of coastal desertification and sand-drift; mapping of soil quality in relation to agriculture in the early modern period 1500–1800 as well as maps related to the management of water regimes (Fritzbøger, 2009; Jacobsen, 2005). Most environmental problems stemming from human resource use are in their nature spatial and the monitoring and regulation of such is to a wide extent based on collection and analysis of spatial data. In the 1960s, the environmental consequences of the rapid economic development of the modern industrial economy became increasingly evident, and consequently led to a change within the mapping of the environment, from a focus on potentials for increasing productivity towards monitoring and regulating of the negative impact of human interaction with the environment (Fritzbøger, 2004, pp. 272–287). Due to the high share of agrarian land cover types in Danish landscapes, the increased environmental pressure on rural landscapes in the post-war period became a particularly important issue for environmental management efforts. Consequently, a large number of maps were produced to monitor agricultural land use intensification and the consequently loss of small biotopes, biodiversity and pollution of riverine and coastal aquatic environments (Brandt *et al*., 2001; Dalgaard *et al*., 2014; Det Grønne Kontaktudvalg, 2012). Today, the production of spatial data and maps relevant to the assessment, monitoring and regulation of the environment in Denmark, has increased to unprecedented heights. This development is also related to the general effort in Denmark to develop a national spatial data infrastructure (NSDI). Besides, efforts have been made for the development of uniform base maps for environmental monitoring purposes, based on the vast amount of spatially explicit administrative data available through government agencies. As such, it may be relevant to conceptualize the development of environmental cartography as a historical parallel to the long tradition in the Danish society for developing cartographies to deal with spatial dimensions of different societal problems, such as the development of cartography for the

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economic delineation of land in the form of property maps and cadastres as well as the military production of topographic maps for fighting in the landscape (Svenningsen, 2014, 2015, in press). However, the development of a tradition for environmental cartography is not unique to Denmark. In fact, several other countries as well as supranational organizations have developed quite extensive mapping programs and spatial data infrastructures (SDI) for environmental monitoring and management (Masser, 2009). An early example is from the former German Democratic Republic (GDR), where cartographic descriptions of the geo-ecological potential of rural land and related possibilities and constrains for human land use, was a fundamental part of the regulation of landscape management (Bastian and Steinhardt, 2002). Other national examples include the Belgian Ecological Evaluation map and the several initiatives in United Kingdom of land use, landscape and soil mapping as well as establishment of rural data infrastructures (Blust *et al.*, 1994; Haines-Young and Watkins, 1996; Perkins and Parry, 1996). While supranational examples counts the European programme for Coordination of Information on the Environment (Corine), e.g. the Corine Land Cover map, the EU Shared environmental information system (SEIS) and the USGS national base-map (Commision of the European Communties, 1991; European Commission, 2013; Heymann *et al*., 1994; Kelmelis, 2003).

Defining environmental cartography

Within the history of cartography, relatively little attention have been devoted to the study of the growing body of maps and spatial data focusing on environmental issues. This is rather surprising, due to the importance of this type of cartography in the handling of the complex environmental issues of modern society, although some studies questioning the use of maps in relation to environmental science can be found, such as (Hauck *et al*., 2013). Within the field of environmental history, Christensen (2013) evaluates the development of maps in New Zealand from their initial role in mobilizing and capitalizing natural resources to their later purpose as instruments to monitor and regulate environmental risk (Christensen, 2013). These attempts to discuss the role of maps and mapping in relation to environmental management are however not addressed within the history of cartography. Although several classification systems for maps exist, which classify maps based on the themes, the phenomena they are dealing with or their spatial coverage, the term *environmental cartography* is not included as a classifier for maps in standard works on map librarianship, such as Larsgaard (1998). Themes such as land use, vegetation, soil, hydrology and others classifiers are used to describe subsets of the historical record of environmental cartography, but this results in a fragmented and in most cases unsystematical approach to the subject (Larsgaard, 1998, pp. 117–155). As a result of this archive-like classification-tradition, current scholarship does not fully grasp the phenomenon of environmental cartography, which is characterized not by its subject matter but by the character of the cartographic practice motivating and delimiting the production of environmental maps. Seen from a practices approach to the study of the history of cartography, environmental maps are dealing with representations of data focussed at the assessment of potential for exploitation, monitoring of change and regulation of risk, in relation to dynamics in natural- and semi-natural ecosystems or human intervention into such ecosystems (Edney, 1993, 1996; Kitchin and Dodge, 2007). These types of cartographic practice can be grouped under the term 'Environmental cartography'. The term naturally relates to a wide variety of maps, with different subjects and purposes. However, environmental maps are characterized by one or a combination of the following aims: (1) assessment; (2) monitoring; or (3) regulation of the nature–human interface. A group of maps deals with a specific phenomenon, while other maps are developed to provide a general spatial infrastructure for the management of the environment (Haines-Young and Watkins, 1996). In a Danish context, environmental cartography can be divided into two standard types of maps, distinguished by their purpose and function. (1) maps which deal with a specific phenomenon relevant to the assessment of potentials or regulation of the environment, which can be classified as *environmental special purposes maps* (ESPM); and (2) maps which are focused on providing a broad cartographic representation of the environment, often related to multiple combinations of interrelated purposes, which could broadly be labelled *environmental base maps* (EBM). These concepts are a good way to differentiate the different cartographic practices related to the environment, e.g. maps dealing with potentials or constrains of agents towards the nature and maps that provides data for analysing and identifying driving forces behind changes in nature as results of human and natural processes.

Methods and materials

The paper is investigating the hypothesis, that:

- Mapping of the environment constitutes a special set of cartographic practices related to the assessment of potentials for exploitation, monitoring of change and regulation of environmental risk, which over the years has developed towards constituting a cartographic paradigm.

The aim of this paper is to analyse the hypothesis in relation to how mapping focused on environmental issues in the Danish landscape developed as a cartographic practice. Although empirically focussed on the cartography related to the terrestrial environments of rural landscapes, the results are likely to be applicable to cartography related to other parts of the environment such as environmental aspects of coastal, oceanic, subterranean and atmospheric spaces. The paper presents two scopes of investigation: (1) an analysis of the general historical development of the broad variety of spatial data and maps related to the terrestrial environment in Denmark; and (2) an analysis of the first environmental base-map in Denmark, the area information system (AIS) land use dataset. This map is included in order to analyse the cartographic practices of an EBM in detail, such as the need for a continues mapping of land use, which generally is not included in traditional standard maps, such as topographic maps.

The general history of environmental maps in Denmark presented in the paper is based on a selected set of the most significant environmental maps and cartographies produced.

Consequently, it is not an ambition of this paper to give a detailed description of all maps and spatial data produced in relation to the environment in Denmark, but rather to unfold the development of the practices of environmental cartography in relation to changes in society. Environmental mapping on the massive scale currently being employed is a relative recent phenomenon in Denmark. Consequently, most of the source material for a study of environmental cartography is available in technical descriptions of different maps and datasets, or is available in scientific literature. However, in some cases, especially regarding the older maps, secondary sources, such as historical descriptions and analysis, has been used. Maps have also been available in different formats. Some maps, especially the older ones, have been accessible as traditional printed maps, while most of the environmental cartography from the 1990s and later, has been available primarily as digital datasets for use in a Geographic Information Systems (GIS). This trend highlights the increasing need for the subject of history of cartography to move into the field of digital cartography.

THE HISTORY OF ENVIRONMENTAL MAPPING IN DENMARK

The practices approach to cartographic analysis proposed by Edney implies an interdisciplinary methodology, which includes other historical disciplines in order to provide the social and cultural context for the development of environmental mapping practices (Edney, 1996). Consequently, the development of environmental policy in Denmark, is used as a framework for the analysis. In this context environmental policy is defined broadly as the set of official discourses objectifying and regulating the use of ecosystems and land areas within the Danish political system. The Danish political scientist Anders Branth Pedersen has analysed the development of nature policy in Denmark. He identifies three historical phases of Danish environmental policy:

(1) A land reclamation phase (1866–1970)
(2) A status quo phase (1970–1985)
(3) A nature restoration phase (1985 – present) (Pedersen, 2006, p. 306).

This seems to be a promising framework for understanding the changes in the mapping practices of the Danish environment and nature.

Environmental cartography for land productivity

Maps and cartography has for centuries been used as a tool to assess land productivity, to evaluate potentials for improvement of the productivity of land use systems as well as identification of environmental risks. This has been especially explicit with respect to the agricultural reforms in Denmark at the end of the eighteenth century. The agricultural reforms, which resulted in a complete enclosure of Danish agricultural landscapes between 1707 and 1860, necessitated the production of a national coverage of soil maps, which could form the basis of court decisions regarding how to subdivide the land. This created the foundation for the first cadastre in 1844, which was updated regularly and remained the most important instrument for land use regulation in the Kingdom of Denmark for over a century (Madsen, 1992). However, economic and planning issues was not the only drivers for surveying of the Danish territory at the time. During the nineteenth century the country was surveyed by the military, creating the first detailed topographic map coverage of Denmark. Although primarily focused on the military need for maps of the terrain, the skills of the military surveyors were also used in relation to infrastructural projects, such as meadow irrigation and constructions of railroad lines. Topographic maps has also been widely used as base maps for many environmental special purpose maps (Svenningsen, 2014). Military officers were also involved in surveys during the two wars over Schleswig (1848–1850 and 1864) as well as with road- and railroad development. Thereby they got a first-hand experience with the vast extent of heathland that covered large parts of the Danish landmass until 1950s, especially in Jutland (Olwig, 1984; Sand-Jensen, 2006; Arildsen, 2013). The reclamation of the great heath in Jutland, which by the middle of the nineteenth century covered about 40% of the peninsula, has been a significant event in Danish history, because it in time provided new agricultural land, which was particularly needed after the Danish defeat to Germany in 1864 (Olwig, 1984). Military personal was an important background for the establishment of the private company Hedeselskabet (The Heath Company) in 1866 with Enrico Dalgas, a former engineer officer, as the first director. The company had a strong impact on land reclamation on the vast moors of Jutland, which were developed into arable land and plantations. Sophisticated methods for mapping different potentials for land improvement were used to pursue this goal. Cartography played a central role, both as a practical tool for the work with land reclamation and soil improvement, but also as a way to convince policy makers to support the projects proposed by illustrating the great surplus of land ready to be cultivated. Another important example of the use of cartography in environmental management was the nationwide mapping of the potentials for soil improvements in Denmark initiated in the 1920s. The long-term goal was to provide every property with an assessment of the potentials for and need for soil improvement (Pedersen, 1971). The three examples given above illustrate the existence of a *land reclamation phase* in the history of Danish environmental policy, as described by Pedersen. According to this, the cartographic practices in relation to the environment focused on providing data which could increase the agricultural area as well as the productivity of existing agrarian and silvicultural land use systems, as exemplified in (Figure 1). The map displays the result of a survey related to the assessment of agricultural land in order to increase agricultural productivity. The detailed map clearly indicates the need for drainage, soil improvement (by adding chalk or lime to lower soil acidity). The map also includes an assessment of the physical geographic conditions of the land, such as the energy impact by the sun and the corresponding warming of the ground during springtime. As such, the map constitutes a prime example on an environmental map focusing on the potentials for productivist land use improvement in the agricultural sector (Wilson, 2001).

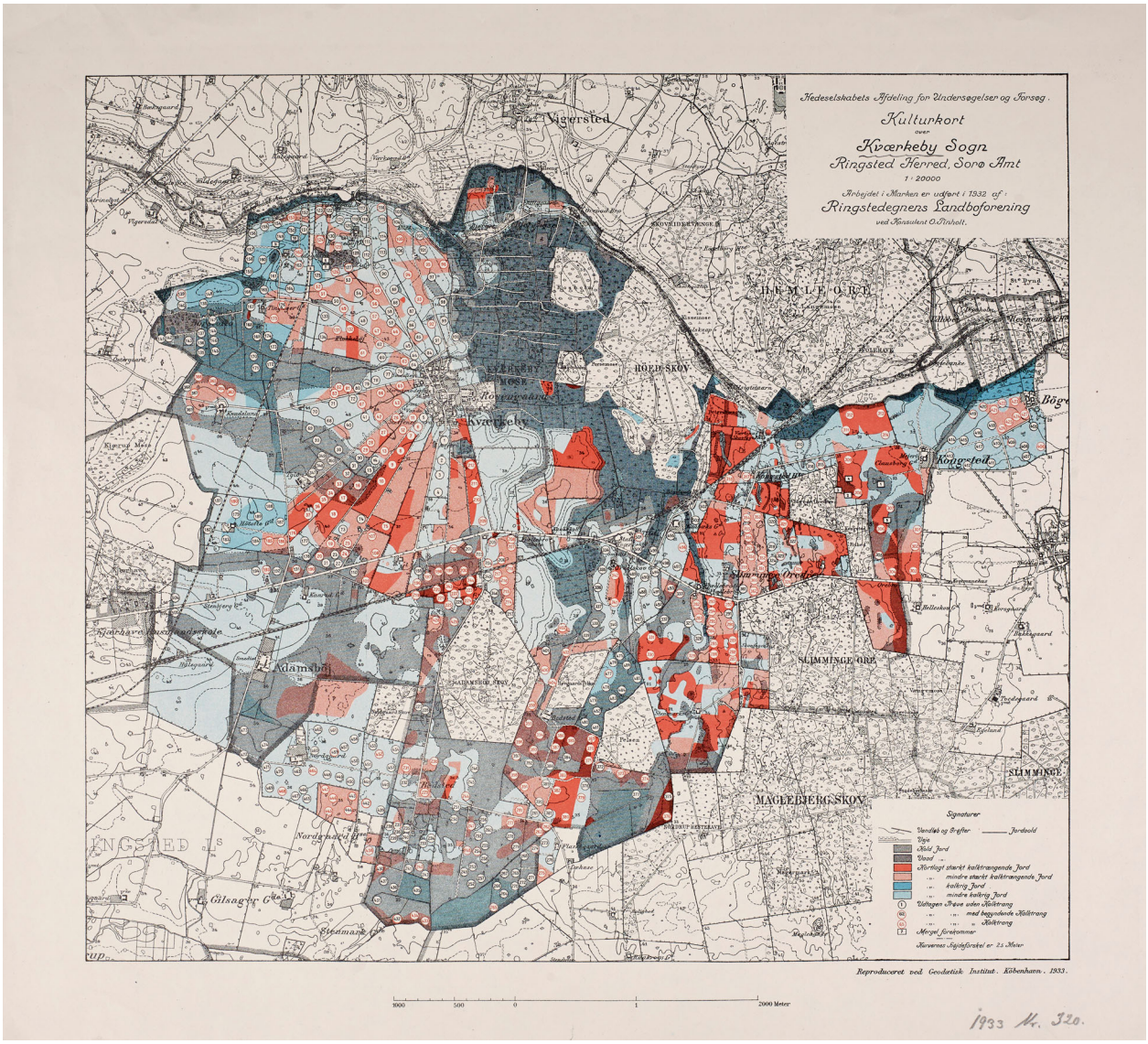

Figure 1. A land assessment map of Kværkeby parish published by the Heath Company on behalf of the local agricultural association in 1933. The need for chalk (to lower soil acidity) is indicated with a blue/red color gradient. Numbers indicate sample sites, a round frame is assessment of chalk content in the soil and a squared frame indicates the presence of local chalk resources. In addition, the dark shaded areas indicate wet or cold soils (refers to the slow heating of soil during spring). The base map is a standard topographic map of the time. Source: The Royal Library 2015.

Environmental cartography for multiple goals

In the latter half of the 1960s, a general concern about the state of the environment started to emerge in Danish society. The emerging environmental movement grew in importance and became affiliated with different scientific communities at the universities and NGO's, putting scientific weight behind the demand for improved environmental regulation. The state responded to this public demand by implementing different environmental regulations and by increased scientific focus on the environment (Illeris, 1999, pp. 367–368; Fritzbøger, 2004, pp. 268–272; Pedersen, 2006, pp. 136–139). One example, from the late 1970s, is the growing attention towards changes in the rural landscape as consequence of agricultural production and the corresponding decline of natural and semi-natural habitats. Initially, landscape change was quantified in case studies based on field surveys and analysis of topographic maps undertaken by counties and municipalities (Agger *et al.*, 1986). In the 1980s, a more systematic research program was initiated in order to monitor landscape change in larger parts of the country. Mapping of the extent, character and number of interstitial habitats in the countryside (labelled *small biotopes* because the investigators employed a biological terminology) became one of the key instruments for monitoring environmental change at this time. In 1981 the state of small biotopes was surveyed in 13 case areas, each measuring 2 × 2 kilometres in size, as a basis for the development of a more comprehensive national monitoring system making it possible to measure landscape change (Agger *et al.*, 1986). The system was expanded to include 32 study areas from 1991 (Brandt *et al.*, 2001). The relatively large budgets set aside for such monitoring efforts and the direct interest and

involvement of government agencies in the work indicates a shift in the type of environmental cartography produced. It illustrates an emerging change toward an environmental cartography with a greater focus on monitoring and regulation of the environment than previously. Monitoring of changes was an important premise for later regulation of land use through law. However, the development of environmental cartography of this type was not exclusively linked to the focus on protection of nature which was promoted by the environmental movements. Some surveys were more in line with the old productivist paradigm, with a genuine focus on increasing productivity and resource extraction. An illustrative example is the soil inventory initiated in the mid-1970s. Due to the growing urbanization pressure in Denmark at the time, the Ministry of Agriculture initiated a new soil inventory in order to produce arguments for safeguarding the best agricultural land against urban development (Figure 2). The initiative was also supported by the agricultural associations (Madsen, 1992).

The soil assessment program was later expanded to include other data related to assessments of potentials for increasing the productivity of agricultural land use, such as inventories of lowlands and slope gradients, but it also included some assessments of potential environmental risks e.g. areas with a potential for leaching of ochre (Madsen, 1992). In 1986 a research programme, focusing on the identification and assessment of areas with marginal soils was initiated due to the impact of the Common Agricultural Policy (CAP), which had recently led to a perceived marginalization of some agricultural areas. An extensive effort to assess and identify potential marginal areas was launched in order to investigate the environmental impact and to identify potentials for new use of marginal land (Stoltze, 1987). The project resulted in a vast volume of reports and maps. The mapping part of the project was aimed at providing: 'a overview and mapping of the different area-related factors, which was important in the discussion about marginal soil and environmental interest' (Stoltze, 1987, p. 11).[1] The data produced was a mixture of assessments of various environmental factors, inventories of potentials for alternative land uses and mapping of specific phenomena such as the distribution of forest, wetland areas, extensive semi-natural areas etc. Different government agencies and sector research institutions were involved in the project. As such, this was an early form of the extensive mapping practices related to environmental management, which was to come in the following years due to the increasing magnitude of spatially explicit regulation of agricultural subsidies as well as management of environmental hazards. However the project also draw on the old notion of nature policy with its focus on production – now just – the production of nature, forest or energy instead of agriculture.

Environmental cartography for regulation and management of nature

Following up on the results of the marginal soil assessment and other research and monitoring projects such as the small biotope programme, the Danish nature protection law was changed in 1992. The new law expanded the protection of semi-natural areas in the countryside to include many terrestrial ecosystems, especially meadows and wetlands, but also dry meadows, heathland, dikes etc (Danish Ministry of the Environment, 2014). The Common Agricultural Policy (CAP) of the EU was also reformed in 1992, with a change in the subsidy structure that introduced various schemes to limit agricultural production by taking areas out of production (Christensen *et al*., 2014). Altogether, these changes created an increased demand for collection of spatial data about areas included under the nature protection law and of agricultural fields, for the administration and regulation of subsidies. Already in 1987 a national programme was launched to monitor the state of the aquatic environment in relation to different national environmental schemes and later to the EU water framework directive. The programme became known as NOVANA, and in 2004, it was expanded to include additional area types and habitats (Miljøministeriet, 2011). In 1998 the UNECE convention (the so-called Aarhus convention) about public access to government files and data about the environment was signed (UNECE 1998). Article 5 of the Aarhus convention states that:

> (…) (a) Public authorities possess and update environmental information which is relevant to their functions; (b) Mandatory systems are established so that there is an adequate flow of information to public authorities about proposed and existing activities which may significantly affect the environment (…) (UNECE, 1998).

Denmark approved the convention in 2000 followed by the European Union in 2005. The convention was an important step in relation to the later development of systems to make digital geodata about the environment available to the public. In 2003 the European Union implemented the Aarhus convention by approving the directive on public access to environmental information (European Parliament, Council of the European Union, 2003), which was later strengthened by the adoption of the INSPIRE directive (European Parliament, Council of the European Union, 2007). In parallel with the Aarhus convention, a range of different projects designed to develop basic environmental data was undertaken both in a national Danish context and in the EU. The increasing use of geographic data by the Danish government to monitor and regulate the environment developed at the same time as GIS started to gain a foothold outside of the research sector. Consequently, there was a growing awareness of the potential for combining different datasets in GIS. The Danish Ministry of the Environment took the initiative to create the AIS project in 1996, with the purpose of developing and testing the possibility of a common environmental data system for Danish government agencies and research institutions. This was due to a widespread experience with lack of common cartographic base-data in government agencies both at state and council level and a need for updating environmental data gathered in the 1970s and 1980s (Nielsen, 2000). The different themes of the AIS dataset illustrates the character of geodata produced in relation to the environment at this time (Figure 3). Themes and subthemes constitute a mixture of basic data for monitoring and research as well as for administra-

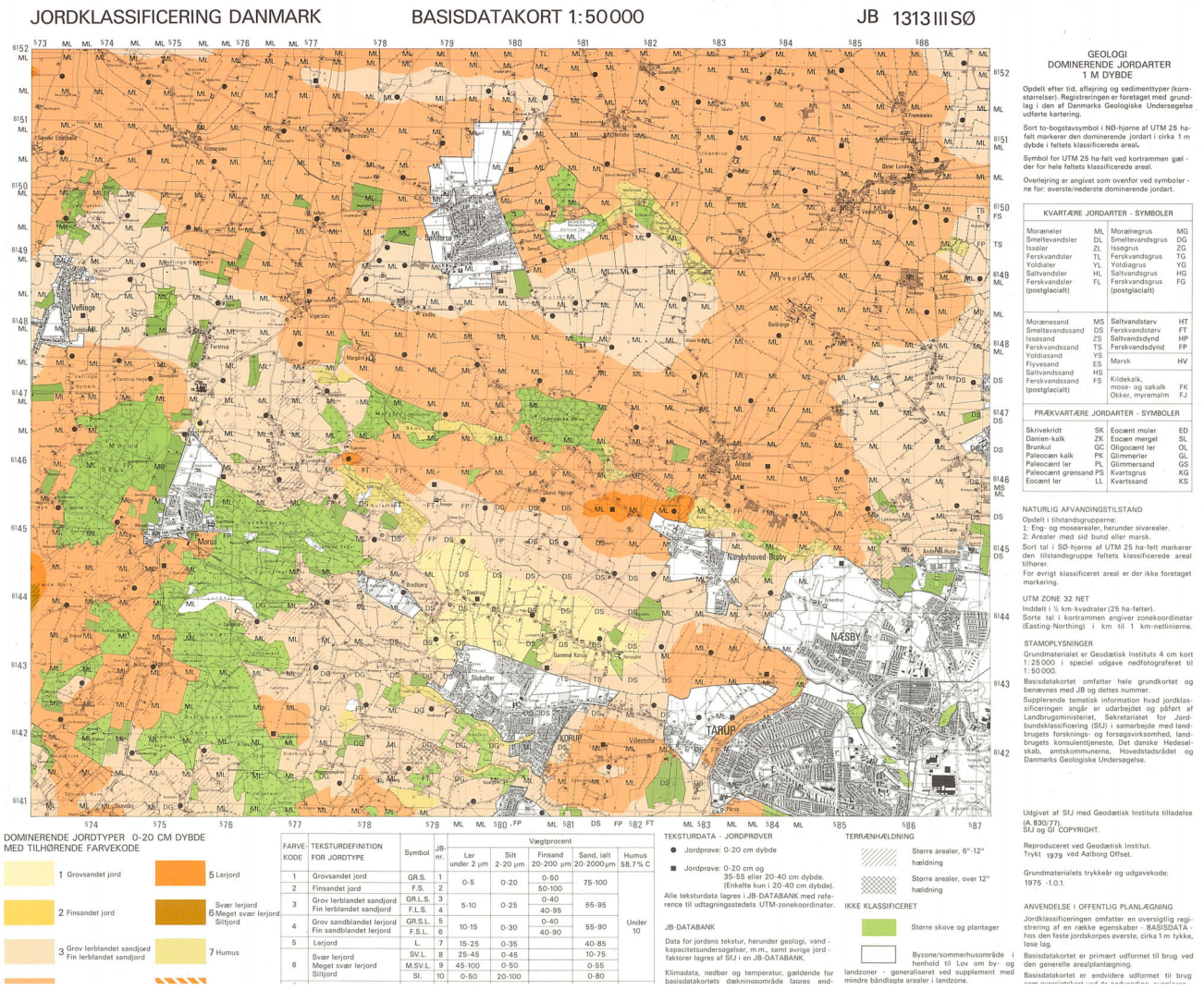

Figure. 2. Map sheet 1313 III SØ in scale 1:50,000 from the soil assessment program. Soil type is indicated with different colours and sample sites is indicated with a black dot. Only land in the open countryside was assessed, excluding urban and forest areas. The map was printed on top of a reduced and black and white edition of the 1:25,000 topographic map, originally produced for the military by the Geodetic Institute. Source: The Royal Library 2015.

tive and legal data control. However, the basic logic behind the AIS data was the acknowledgement that the amount of data had grown to a level where a common framework for environmental geodata would enhance access to data and possibly create synergies between different agencies and research institutions.

Another development, which followed the logic formalized in the Aarhus convention and the AIS initiative, was the establishment of a working group about coordinated production of topographic and technical spatial data by the government and the municipalities. In 1997 the National Survey and Cadastre together with the association of municipalities (Local Government Denmark) started a project about jointly generated digital base-data. The aim was to simplify the data production and possibly unify the technical maps from the municipalities and the digital topographic maps from the National Survey and Cadastre (Flensted, 2003). The uniform production of government geodata resulted in the so-called *common public geographical administration basis*, abbreviated FOT (FOTdanmark, 2014).[2] This was a new approach to the production of standard maps in Denmark. The principle idea was that all changes made to certain datasets administrated by municipalities or other public administrations, with relevance for the production of topographic base data was updated by the National Survey and Cadastre as soon as the changes were made. In this way, the production time and administrative cost of maintaining the background geodata infrastructure in Denmark was to be reduced and to be more efficient. In 2007, the administrative structure in Denmark was reformed. Until then the counties had been the responsible authority for environmental regulation and monitoring. In order to secure the data held by the counties a digital platform for management and access to environmental data was established in cooperation between the state, the old counties, the new regions and the municipalities. The aim was both to safeguard the data held by the

AIS themes and subthemes

Land use	Other base map	Hydrology	Planning	Nature - and cultur protection	Resources	Polluted and technical areas	Tourism
Land use map	Satelite data archive	Water courses	Municipality planed urban frontiers	Protected nature types (§3)	Watersupply interest areas	Waste depots	Camping
	Land cover map	Lakes	Urban zones	Nature and wildlife reserves	Areas for raw material extraxtion of the seabed	Windmil areas	Hostels
	Land cover map (plus)	Small lakes	Delineation of villages	EU-Habitat (Natura2000) areas			Hotels
	Classification of buildup areas	Current wetlands	Local plans for rural zone	EU-Bird protection areas			
	Danish soil types (1:25.000)	Catchment boundaries	Zones for holiday homes	Ramsar areas			
	Danish soil types (1:200.000)	Monitoring stations (rivers)	Planned zoning for holiday homes	Protected areas			
	Seabed types			Protected lines			
	Deepth model for inner Danish waters			Protected points			
	Cost and country boardes (three different types)						
	Sea around Denmark						

Figure 3. Illustrates the different themes and subthemes included in the AIS. The themes constitute a mixture of legal protection, planning, technical and basis data. Even data for tourism has been included. As such, the system reflects the spatial datasets held by different government agencies and research institutions at the time 1996 (Nielsen, 2000, pp. 9–10).

counties, but also to enhance the spatial infrastructure for environmental management. Also the need for harmonizing the environmental data across administrative levels was an important ambition (Vinther *et al*., 2007). The development of such infrastructures was instrumental to the implementation of changes in the environmental policy, which since the 1980s had developed toward an increasingly comprehensive focus on nature restoration and environmental protection. The diversity of the still increasing use and production of cartographies in relation to the environment are illustrated by the range of different projects. One example relates to the Danish ratification of the European Landscape Convention in 2003. This promoted a more holistic cultural-historical focus on the landscape and has been partly implemented through landscape character assessments, as way to evaluate the potential utility and cultural history of rural landscapes (Caspersen and Nellemann, 2005). In the policy recommendations published by the Danish commission on nature and agriculture from 2013, a new approach toward environmental regulation was outlined, emphasizing that the regulation of pollution from nutrients from agriculture should be regulated at local scales, based on maps detailing the geo-ecological capacity of each specific area in use (Jespersen *et al.*, 2013). Such an approach to regulation demands a comprehensive mapping of the geo-ecological properties of the landscape, which is not yet available. The future development of such datasets, in combination with the intentions to use them as tools to implement new local scale management regimes could indicate a return to a more economically oriented mapping of potentials in the landscape, now just oriented towards the economic potential in recreation and settlement as well as the potential of the soil to absorb and filter surplus nutrients and other inputs introduced through intensive agricultural land use. This is also the case with respect to the mapping of so called *High Nature Value Farmland* in Danish landscapes, ordered by the Danish AgriFish Agency in 2012 and the national map of biodiversity ordered by the Nature Agency in 2014 (Ejrnæs *et al.*, 2012, 2014).

Trends of the environmental cartography in Denmark 1866–2014

As illustrated in Figure 4, several maps were produced in Denmark with a focus on management or monitoring of the environment, which changed from a focus on potential for production and risk management towards environmental protection and management of ecosystem services. This was in line with the shift in nature policy to focus mainly on nature restoration. Another interesting pattern in this review is the primacy of the ESPM over the EBM. Besides from the AIS land use and land cover maps, all other EBM has either been produced by supra-national institutions or by researchers within a specific, specialized field such as the base map from Aahus University (Levin *et al.*, 2012).

THE CARTOGRAPHIC PRACTICES OF ENVIRONMENTAL BASE MAPS

As described in the previous section, the AIS project included a number of subprojects. The following will focus on the AIS land use map as being an example of an environmental base

map (EBM). The aim of this AIS land use dataset was to provide: '(…) a stable digital topographic framework in scale 1:25 000, which can provide a uniform map of the land use in Denmark, from a nature- environmental perspective.' (Nielsen, 2000, p. 20).[3] The statement illustrates that the traditional nationwide spatial standard-datasets, such as topographic and cadastral maps, were less useful for the monitoring and management of the growing amount of environmental regulations and policies – making the production of standardized environmental base-data necessary. The map also provided a uniform nation-wide statistical data source, which could be used for monitoring of change in the landscape if the system later was to be updated. Developing such a new base-map was however not a simple task and several obstacles had to be overcome. One of the major problems with the traditional topographic maps was the lack of land use classifications for a large part of the land and consequently filling out the *blank* part of the topographic maps was an important part of the AIS project. The AIS land use map was developed by combining different data sources, such as topographic maps, environmental and agricultural land use management data and remote sensed data. Figure 5 illustrates the difference between the two basic data sources of AIS, topographic maps and the administrative data from management of protected nature areas (§3), and the final layout of the AIS land use data. The fact that the AIS base-data was based on an interpretation of these two data sources had several implications. Most importantly, the two maps which were combined in AIS were originally designed to represent a military or habitat management-oriented view of the landscape respectively, ignoring features irrelevant for their main purposes. Therefore the two data sources provided geometrically precise information (topographic maps) and field based data on the location and character of single habitats (nature protection maps). But because the topographic maps were not developed to provide land use data for environmental purposes, but rather a description of land cover in relation to military mobility in the landscape, the information on land use was limited (Svenningsen, in press). The nature protection map was focused on the habitats defined within the nature protection law, leaving even more extensive gaps in the land cover and land use information. Therefore, additional data were used to fill these gaps (Figure 6). This came both from register-data derived from records held by the agencies administering agricultural subsidies in connection to the common agricultural policy of the European Union, and from a land cover map based on remotely sensed satellite data.

The AIS land use map reflects the need for a new basic cartographic representation of the landscape, designed to support the management of the environment. The AIS land use data has however not been updated after the launch in year 2000, and the actual use is difficult to assess. However, due to the increasing demand for spatially explicit land use and land cover data for monitoring and modelling purposes often with a global coverage, such as in connection to the Kyoto protocol, there has been a growing need for environmentally oriented base maps. The EU Corine land use data (1990, 2000 and 2006) is widely used and there are some indications on the demand for nationally produced environmental base maps, such as the base maps produced by Aarhus University in 2012 and by Copenhagen University (Christensen, 2012; Levin *et al.*, 2012). However, the EBMs are related to regulation and management of the environment at a different scale than the ESPM. The EBMs are more focused toward a general statistical description of the environment, which can be compared over time and which changes can be held against. However, the discontinuation as well as development of different EBM's constitutes a problem in relation to changing land cover and land use classification systems, which can make analyses of changes over time difficult (Cassettari, 2003). However, while reclassification of datasets can solve some of this problem, more attention should also be focused on the categorical bias of the different datasets combined into EBMs (Jepsen and Levin, 2013; Straume, 2014; Svenningsen *et al.*, 2015).

A NEW PARADIGM OF ENVIRONMENTAL CARTOGRAPHY?

The results of the analysis suggest that a growing body of maps have been produced in relation to the environment and the human–nature interaction. Today spatial data and digital maps form the main administrative data component in the management and regulation of almost all area-related activities in Denmark. It is evident that the environmental cartographic practices constitute a specialized representation of the landscape, which differs from traditional topographic and cadastral maps. What constitutes this cartography are the relation to the human–environmental interface, although the purposes and objective of Danish maps oriented towards the environment have changed over time in relation to shifting environmental policies. Historically the management of environmental risk and a desire to raise the productivity was the main objectives of environmental cartography. Today the protection of habitats, environmental zoning and the management of agricultural subsidies, have become the predominate purposes. This development of environmental maps and spatial data is not unique for Denmark, quite the opposite (Brandt *et al.*, 2002; Bunce *et al.*, 2007; Ståhl *et al.*, 2011).

However, a fundamental difference exist within the environmental cartography in relation to the purposes and approach to the environment. As proposed in the introduction, two types of environmental maps can be distinguished; the *environmental special purposes map* and the *environmental base map*. In a paper on the political geography of environmental management, the Swedish geographer Torsten Hägerstrand define two basic approaches to the regulation of the complexity of human actions towards the environment. The first approach aims at understanding the driving forces behind human action and the second seeks to identify constraints for human action. In this context, Hägerstand introduces the concepts of *territorial* and *spatial* competence as well as *technological* capabilities of actors in relation to agency in the landscape (Hägerstrand, 2001). The difference in the two approaches to the human regulation of the environment, suggested by Hägerstrand; the *driving force* and the *potential* approach, seems to offer a good starting point for a discussion of the differences between the two types of environmental maps as well as providing a possible

Historical overview of maps and spatial datasets related to the environment in Denmark

Name	Year	Organization	Type	Purposes	Data source	Scale	Format	Coverage	Relation to policy
Soil classification in relation to the enclosure	1757 - 1850	Rentekammeret (treasure department)	ESPM	Classification of soil as a base to distribute land in connection to the enclosure and for taxation purposes	Field survey	1:4.000 - 1:8.000	Manuscript map	National	Production
Forest maps	1763 -	Forest districts	ESPM	Management of forest stands	Field survey	1:4.000 - 1:20.000	Manuscript map	Local / regional	Production
Kulturkort (agricultural potential maps)	1919 - 1930s	Private company, partly goverment funded	ESPM	Soil improvement	Field survey, topographic maps as base maps	1:20.000 / 1:10.000	Printed maps	Local (national coverage intended)	Production
Moseundersøgelserne (Bog assessments)	1923 - 1939	Private company, partly goverment funded	ESPM	Assessment of the economic potential for rawmateriale extraction	Field survey, topographic maps as base maps		Printed maps / book	National	Production
Soil classification	1970s - 1980s	Ministry of agriculture in cooperation with consultants of local farmer organizations	ESPM	Soil assessment and clasification of dranige need etc.	Field survey, interviews	1:50.000	Printed maps / digidat data	National	Production / regulation
Small biotope monitoring program	1986-1996 (2001 - present)	Roskilde University / Natyrstyrelsen	ESPM	Environmental monitoring	Field survey, aerial photographs and topographic maps	1:10.000	Vector data	Sample areas	Monitoring
Marginal soil inventory	1986	Ministry of the Environemt	ESPM	Assessment of marginal soil		1:100.000	Paper maps / digital data (vector)	National	Production (of nature) / monitoring
§3 registration	1992	Naturstyrelsen	ESPM	Environmenat managment	Field survey		Paper maps / digital data (vector)	National	Monitoring
GLR - agricultural registration	1993 - present	Ministry of Food, Agriculture and Fisheries of Denmark	ESPM	Management of agricultural subsidies	User data / Registerdata			National	Regulation
CORINE	1996 - 2006	European Union	EBM	Base map	Remote sensing, topographic maps and aerial photographs	1:100.000	Raster	European	Monitoring
NOVANA	1998	Naturstyrelsen	ESPM	Environemental monitoring	Field survey				Monitoring
AIS (Area information system) LU (100)	2000	Ministry of the Environemt	EBM	Environemental protection / managment	Topographic maps, register data, remote sensing	1:25.000	Vector	National	Monitoring / regulation
Landscape character mapping	200?	Municipalities	ESPM	Environmental management of cultural landscape	Topographic maps, field survey			Regional	Regulation
HNV indikator kort	2012	NaturErhvervstyrelsen / Danish centre for Environment and Energy	ESPM	Environmental protection	FOT (coast line, hedegrows, forest egde, krat, fortidsminde), Lavbund, LIDAR (relief), §3 registering, GLR (organic fields, ekstensive use), spices data DanBIF, Danmarks Svampe Atlas, 6 stjernearter (NOVANA), Danmarks Naturdata (habitatsdirektivet)	9,6 * 9,6 meter	Raster	National	Production (of nature)
Base map	2012	Danish centre for Environment and Energy	EBM	Base map	Topographic and register data	10 * 10 meter	Raster	National	Monitoring / regulation
Biodiversity map of Denmark	2014	Naturstyrelsen / DCE	ESPM	Mapping of biodiversity	Indicators (geodata) and population counts of specific species	10 * 10 kilometer	Raster	National	Regulation and management

Figure 4. An overview of the most important datasets and maps dealing with the Danish landscape in an environmental perspective, from the nineteenth century to present. A change toward an increasing focus on monitoring and regulating the environment can be observed in the 1990s which is in line with the change in nature policy identified by Pedersen (2006).

explanation for the primacy of the ESPM. Hägerstrand highlights the *potential* approach as more simple and operational to apply in environmental management, because it directly relates to the regulation of the territorial competence of human agents in the environment (Hägerstrand, 2001). As such, the ESPM has been well suited for management of a set of limited environmental goals – being increasing productivity or simple environmental risks, such as sand-drifting. However, the growing awareness of the environmental problems in the 1960s, has led to an increased scientific interest in the environment and a corresponding awareness of the complexity of environmental problems. This have paved the road for a more comprehensive type of environmental maps, the EBM. These were related to the identification of and assessment of the rate and scale of changes in nature as a product of human activity. As such, the scientific oriented environmental cartography to a large degree fall into the second approach to regulation of human actions towards nature: the *driving force* approach. The small biotope monitoring program and the AIS map are illustrative examples

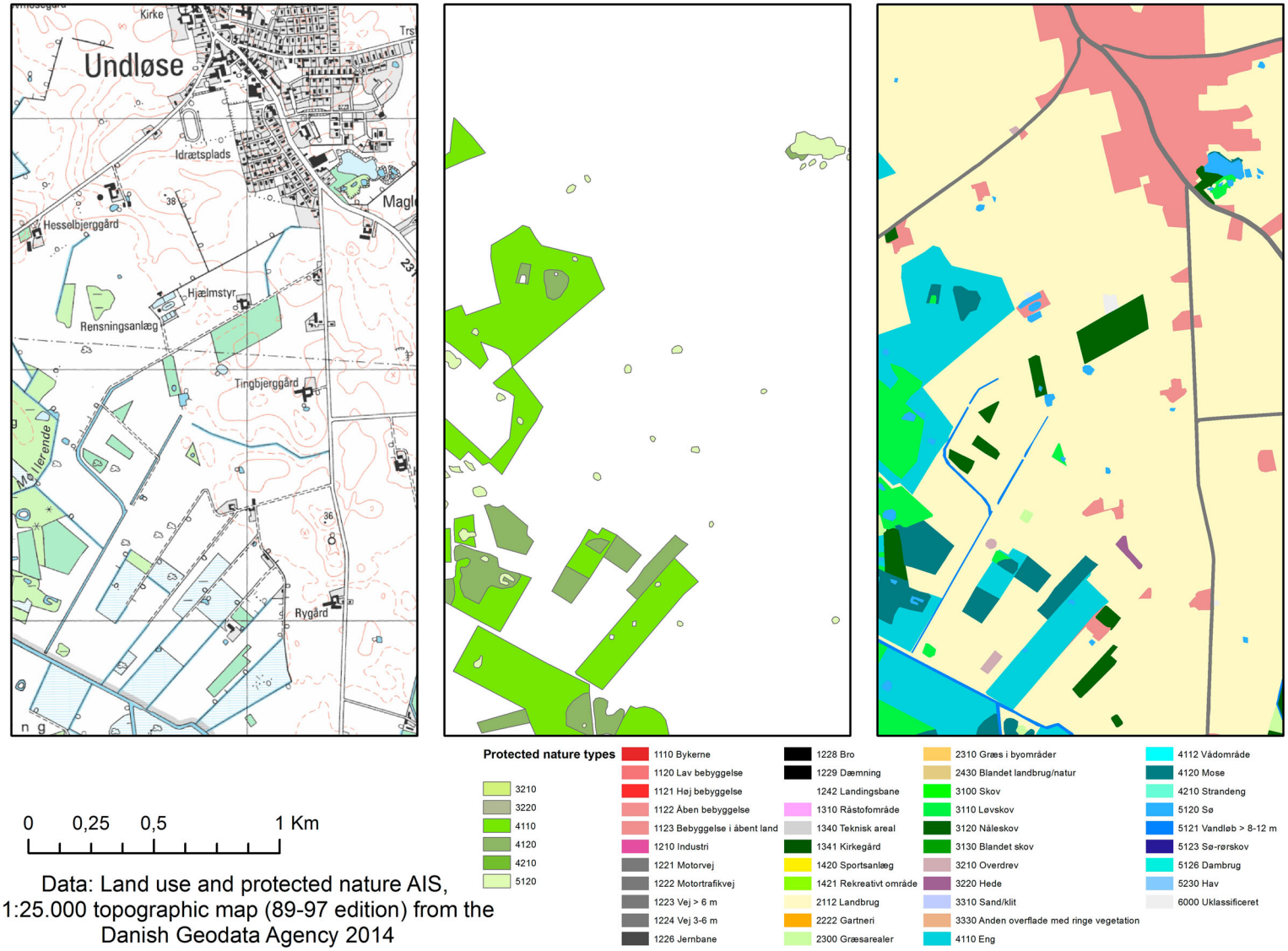

Figure 5. An illustration of the differences between a traditional topographic map (left), administrative data from management of protected nature types (centre) and the land use map from the final AIS dataset (right). The use of the geometry from the topographic map and the data on protected nature is evident. Other data were used to fill up the areas not classified in the two maps. However, besides the geometry the AIS map also dependent on the classification of the landscape in the topographic map, especially concerning categories of land cover such as forest and meadows.

AIS Land Use map (data sources)			
Data origin	**Data layers**	**Data types**	**Use in AIS**
KMS	Ditches and streams (A26)	Topographic data	Priciple geometry and classification, based on weighted choice
	Water Areas (sea, large rivers, lakes)(A27)		
	Meadows (A28)		
	Coniferous forest (A37)		
	Deciduous (A38)		
Registartion of protected nature types §3	Grasslands (overdrev)	Compilation of register data from counties	
	Moors (heder)		
	Lakes		
	Wet meadows (fersk eng)		
	Bogs		
	Marsh land		
	Salt meadows		
Agricultural register data from the Ministry	Agricultural area	Data derived from registation of agricultural subsidies	Classification of residual areas
	Areas within the fields, with no agriculture		
	Potential roads - and other linear features within the area of agricultura		
	Town, scattered buldiengs and farms		
Land Cover Map (produced under the AIS project)	Seasonal land cover	Produced speciffically to the project	Classification of residual areas
	Grazed or mowed grass		
	Meadows		
	Bare surface		
	Deciduous		
	Coniferous forest		
	Bush and forest areas		
	Grass covered moorland		
	Bush and grass covered moorland		
	Bush covered moorland		
	Open water		
	unclassified		

Figure 6. Data used in the AIS land use map. A major part of the data was taken directly from the Danish Survey and Cadastre and the data registered in connection to management of protected nature types from the Danish counties.

of this, as they present a collection of data to identify trends and to make statistical analysis of the consequences of human action towards nature. International examples of such maps are the national map project in the Unites States and the European Corine land cover map (Bossard *et al.*, 2000; Kelmelis, 2003). Today EBMs are increasingly utilized for modelling of land change processes, CO^2 emissions and policy impact, often at global and regional level as well as for comparative studies of different regions and countries. Although the new technological possibility with digital cartography and GIS systems, have made the development and distribution of EBM's more easy, relative few such maps have been produced. This is also evident in the content of the Danish Environmental portal. Although the portal offers easy and efficient access to several different environmental maps, it in reality only presents a collection of ESPMs, overlaid on aerial photographs mosaics or traditional topographic maps. This is probably due to that the EBM are much less applicable in the direct implementation for policy measures, as the environmental policy in Denmark has been divided into sectors, which could be a part of the explanation of the relative few EBMs produced in Denmark compared to the number of ESPMs. However, the ongoing implementation of the INSPIRE directive, including a new open-data strategy, as well as organizational changes within the Danish geo-data institutions, could provide a SDI, which could enhance the production and distribution EBMs (Masser and Crompvoets, 2015).

The concept of environmental cartography, which is presented in this article, is addressing an evolving phenomenon within the history of cartography. Some of the characteristics of cartographic practices related to the environment have been described and two general types of maps have been defined. Although the concept of environmental cartography could be improved and clarified in relation to a more comprehensive overview of cartographic practices, the concept does serve to address an important part of the history of cartography. More research should be devoted to studies of this kind of cartography, because it is an important part of our present cartographic history and because such studies would supply researchers with important opportunities to reflect on the relevance and rationality of the practices of environmental cartography which are currently being enacted – a reflective stance which is in much need within the environmental research sector.

CONCLUSION

During the period between 1866 and 2014, the focus of environmental mapping of terrestrial landscapes in Denmark changed from mainly focussing on assessments of the potential for increasing production to monitoring and regulation of human interaction with semi-natural ecosystems in the landscape. Two general types of maps related to the environment were produced in this period, and their differences correlate with changes in the environmental

policy regulating human practices in the landscape. Environmental special purpose maps primarily focus on identifying the possibilities and constrains affecting agents managing the landscape, while environmental base maps generally focus on scientific documentation of changes resulting from human actions and related driving forces. As such, the cartographic practices related to mapping of the environment in their various forms seem to constitutes specific groups of maps and spatial dataset, with a distinctive character. However more research should be devoted to this specific part of the history of cartography, as it constitutes an important an evolving part of our cartographic legacy.

BIOGRAPHICAL NOTE

Stig Roar Svenningsen holds a MSSc degree in history and geography from Roskilde University, 2010. In 2015, he received a PhD in geography (Spatial sources to the landscape: historical cartography and aerial photographs in geography and landscape research) at Roskilde University and The Royal Library in Copenhagen. Current research covers the history of cartography in Denmark during the 19th and twentieth century and the use of historical cartographic data in history and landscape research.

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Notes

1 Danish text: 'er et ønske om at få et overblik over og kortlagt de forskellige arealrelaterede faktorer, der er væsentlige i diskussion om marginaljorder og miljøinteresser'
2 Original Danish text: 'Fællesoffentligt Geografisk Administrationsgrundlag'
3 Original Danish text '*at udarbejde en stabil digital topografisk ramme i målestoksforholdet 1:25.000, der kan udgøre et sammenhængende kort over Danmarks arealanvendelse, set ud fra en natur- og miljømæssig synsvinkel*.'

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